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(54) FILM THICKNESS MEASUREMENT METHOD AND APPARATUS

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SPECIFICATION

1. Title of the Invention

FILM THICKNESS MEASUREMENT METHOD AND APPARATUS

2. Claims

(1) A film thickness measurement method which is characterized by the fact that a thin film sample placed in a vacuum is irradiated with an electron beam, and the thickness of this thin film sample is measured by measuring the transmission current.

(2) A film thickness measurement apparatus which is characterized by the fact that this apparatus is constructed from a vacuum system that comprises mainly a bell jar and a vacuum pump, an incident electron system that comprises mainly an electron gun that irradiates a thin film sample placed in a vacuum with an electron beam, and a power supply for this electron gun, and a transmission current measurement system for the above-mentioned thin film sample that comprises mainly an ammeter.

(3) The film thickness measurement apparatus according to Claim 2, wherein the above-mentioned thin film sample is a vapor deposition film formed on a vapor deposition substrate.

(4) The film thickness measurement apparatus according to Claim 2, wherein the measurement system that measures the transmission current from the incident electron system for the above-mentioned vapor deposition film is connected to a vapor deposition control power supply for the above-mentioned vapor deposition film via a comparator.

(5) The film thickness measurement apparatus according to any of Claims 2 through 4, wherein the above-mentioned incident electron system comprises an electron lens.

3. Detailed Description of the Invention

The present invention relates to the measurement of the thickness of thin film samples such as vapor deposition films.

Conventionally, film thickness measurement methods have included methods using various types of microscopes, methods utilizing light interference or absorption, and the like. In the case of these methods, however, there are limits to the film thicknesses that can be measured, and it is especially difficult to measure the thickness of thin films.

Furthermore, there are also methods in which accelerated ions are caused to collide with the sample thin film, and secondary ions or light, etc., emitted from the film surface are detected.

However, these methods are destructive measurement methods, and it is impossible to grow the film while measuring the film thickness.

The present invention provides a method and apparatus that make it possible to measure the thickness of a film in a non-destructive manner, and to grow the film while measuring the film thickness.

Next, the principle of the present invention will be described. Generally, a substance has a specific [electrical] resistance. When a substance that is present in a vacuum is irradiated with an electron beam, electrons that are caused to undergo back scattering by the substance and electrons that are transmitted through the substance can be observed. In a case where the incident area of the electron beam is constant, the transmission current decreases with an increase in the thickness [of the substance]. When an electron beam is caused to be incident on the surface of a thin film formed by vapor deposition or the like on the surface of a substrate that has a certain fixed thickness, the current that passes through the thin film and substrate can be measured. In this case, since the transmission current attributable to the substrate is constant, variations in the thickness of the vapor deposition thin film can be detected by variations in the transmission current.

Accordingly, if the relationship between the substance used for the substrate and the transmission current corresponding to the thickness of this substance, and the relationship between the substance from which the thin film is formed and the transmission current corresponding to the thickness of this substance, are determined beforehand, the thickness of a thin film of unknown thickness can be ascertained.

The present invention is based on such a principle, and will be described in detail below in terms of an embodiment. Figure 1 is a schematic diagram of the film thickness measurement apparatus used in the present invention. In this figure, a thin film sample 3 is placed inside a bell jar 2 which is evacuated to a vacuum by means of a vacuum pump 1, and an electron beam that is emitted from an electron gun 5 driven by a control power supply 4 is caused to be incident on the surface of this thin film sample 3. The film thickness is measured by detecting the transmission current that passes through the thin film sample 3 in this case by means of an ammeter 6. Furthermore, 7 indicates the focusing electron lens of the electron gun 5.

As is shown in Figure 2, the transmission current that is measured in a case where the thickness of the film that is formed on the substrate is 0 (i.e., in a case where no film is formed) is the transmission current *a* of the substrate itself, and the transmission current decreases along the curve *C* as the thickness of the vapor deposition film or the like successively increases.

When [the thickness reaches] a film thickness *b* which is such that no current is transmitted, the transmission current becomes 0. Furthermore, the curvature of this curve *C* is determined by the substance involved.

Accordingly, if the vacuum-deposited substance is determined, and the curve *C* of this substance is determined in advance, the film thickness can be ascertained by detecting the transmission current in the case of electron beam irradiation.

Point *b* in Figure 2 is the maximum measurable film thickness that is obtained when the incident voltage is set at a constant value for a certain substance. Furthermore, as is shown in Figure 3, this value increases in accordance with the acceleration voltage for a given substance as indicated by the curve *d*. The curvature of this curve *d* is determined by the substance that is involved.

Figure 4 is a schematic diagram of an apparatus showing one example of the working of the measurement method of the present invention. A vapor deposition film 3 is formed by means of a vapor deposition source 10 (controlled by a control power supply 9) on a vapor deposition substrate 8 inside a bell jar 2 which is evacuated to a vacuum by means of a vacuum pump 1. The surface of this vapor deposition film 3 is irradiated with an electron beam current that is emitted from an electron gun 5 controlled by a control power supply 4, and the [resulting] transmission current is measured by means of an ammeter 6. The film thickness of the vapor deposition thin film 3 can be measured on-site in a non-destructive manner by means of this measurement apparatus while the vapor deposition thin film 3 is formed on the substrate 8.

Furthermore, in cases where it is desired to control the film thickness of the vapor deposition film 3 automatically, [this can be accomplished by using] a comparator 11 to compare the transmission current [values] of the film 3 measured by the ammeter 6, and stopping the vapor deposition control power supply 9 at the point in time at which the specified film thickness is obtained.

Furthermore, in cases where it is desired to ascertain the in-plane distribution of the film thickness of the vapor deposition film, this can be determined by moving the incident position of the incident electron beam on the vapor deposition film in the X-Y direction by means of the electron lens 7 of the incident electron system, and measuring the transmission current at respective positions.

Thus, the following effects are obtained in the case of the measurement method and apparatus of the present invention:

(1) The film thickness of thin film samples can be measured in a non-destructive manner.

(2) Measurements can be made in a broad range, ranging from extremely thin films to relatively thick films.

(3) In cases where the thin film sample is a vapor deposition film, the film thickness can be measured on-site while performing vapor deposition.

(4) Automatic control of the thickness of vapor deposition films is possible.

(5) The in-plane distribution of the film thickness of thin films can be determined.

4. Brief Description of the Drawings

Figure 1 is a schematic diagram which shows one example of the film thickness measurement apparatus of the present invention. Figure 2 is a graph which shows the relationship between the transmission current and the film thickness of the thin film that is obtained when the acceleration voltage of the incident electron beam is maintained at a constant value. Figure 3 is a graph which shows the relationship between the maximum measurable film thickness and the acceleration voltage of the incident electron beam for a specified thin film forming substance. Figure 4 is a schematic diagram of one embodiment of the vapor deposition film thickness measurement apparatus of the present invention.

1... Vacuum pump; 2... Bell jar; 3... Thin film sample; 4... Electron gun control power supply; 5... Electron gun; 6... Ammeter; 7... Focusing electron lens of electron gun; 8... Vapor deposition substrate; 9... Control power supply; 10... Vapor deposition source; 11... Comparator.

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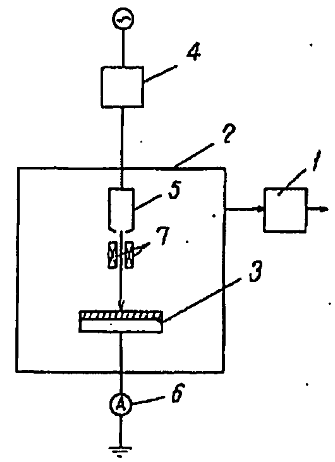

Figure 1

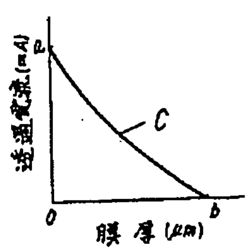

Figure 2
Y axis: Transmission current (mA)
X axis: Film thickness (μm)

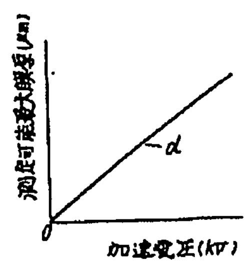

Figure 3
Y axis: Maximum measurable film thickness (μm)
X axis: Acceleration voltage (kV)

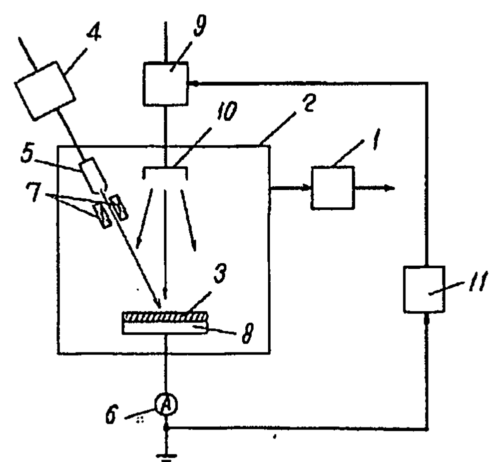

Figure 4